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SPECIFICATION

FLUORESCENT LAMP

FIELD OF THE INVENTION

The present invention relates to a fluorescent lamp and more particularly to a fluorescent lamp that is suited for a light source for the back-lighting of liquid crystal displays that are used in personal computers, car-navigation displays and various electronic devices.

BACKGROUND OF THE INVENTION

Fluorescent lamps are used as light sources for the back-lighting of liquid crystal displays to irradiate uniform light to liquid crystal panels from the back in liquid crystal displays that are used in, for instance, personal computers or car-navigation displays. Accompanied with demands for large-sized, thin and high performance display area of liquid crystal displays, stable and sufficient light intensity, uniform distribution of luminance in the axial direction of lamp tube in the wide temperature range from -40°C to 85° or under the control of light intensity from several % to 100%, are demanded for fluorescent lamps themselves as light sources for the back-lighting jointly for small-sized luminance tube diameter and extended tube length.

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However, because the light intensity of these fluorescent lamps is insufficient at low ambient temperature and mercury may cause the environmental pollution, the development of fluorescent lamps without using mercury gas is demanded.

On the other hand, a small discharge lamp or a fluorescent lamp using inert gas such as neon gas, krypton gas or xenon gas was disclosed in Japanese Laid-Open Patent Publication (Kokai) No. 57-63756. In this discharge lamp, one of two electrodes is provided in a glass tube and the other electrode is provided outside the glass tube. The former electrodes is provided over the almost an entire length of the glass tube along its longitudinal direction and the latter electrode is provided on the outer surface of the glass tube facing the former electrode. It is disclosed that the discharge lamp is a small one having a diameterof 2 to 10 mm and of a length of 50 to 200 mm, used as a luminous display for displaying characters, numerals or symbols by a single or a plurality of straight or bent lamps combined. It ia also disclosed that the discharge lamp is used as energy-saving type pilot lamps or beacon lights.

However, in the case of conventional discharge lamps or fluorescent lamps in such a structure, it is difficult to form an uniform discharge distance to an outer electrode from an inner electrode for the overall length of an inner

electrode and as a result, such problems are caused that a partial discharge is produced and a stable positive column cannot be formed on the overall length of a glass tube. In other words, for back-lighting sources of liquid crystal displays, for example, such a slender fluorescent lamp using a glass tube having an outer diameter of 1.6 to 10 mm in and having a length of 100 to 500 mm is used, and it is extremely difficult in view of manufacturing technology to provide electrodes so as to make a discharge distance uniform for the overall length in a glass tube.

Further, in liquid crystal displays, fluorescent lamps are often subject to the effect of vibration depending on the using condition and an inner electrode is deformed locally. Therefore, it is difficult to maintain a discharge distance always constant.

Furthermore, such glass tubes manufactured in complicated shapes as W tube, U-shaped tube may be used as back-lighting sources in liquid crystal displays. However, in such structure, it is most difficult to make a discharge distance of the inner to the outer electrode becomes uniform over the overall length.

Next, in conventional gas discharge lamps or fluorescent lamps in the structure described above, even if a glow discharge area was formed for the overall length of a lamp and in particular, when a discharge medium containing xenon is used, electrons are actively discharged

around the inner electrode and therefore, a diffused positive column is hardly formed and as a result, the generation of ultraviolet rays is suppressed. Accordingly, when this electrode structure is used for fluorescent lamps having the glass tube, inner wall of which is coated with fluorescent substance for the purpose of emitting a luminance by ultraviolet rays excited, there is such a defect that sufficient brightness cannot be obtained.

Accordingly, an object of the present invention is to solve the above-mentioned problems involved in conventional fluorescent lamps. In other words, it is an object of the present invention to provide a fluorescent lamp for the back-lighting of liquid crystal displays which provide a stable luminescence with a sufficient brightness using rare gas containing xenon-gas as a discharge medium.

SUMMARY OF THE INVENTION

A fluorescent lamp according to the present invention comprises a glass tube both ends of which are sealed airtight filled with discharge medium therein, a fluorescent substance layer formed on the inner wall of the glass tube; an inner electrode arranged at one end in the glass tube and given with one of potentials, and an outer electrode composed of a conductor spirally wound around the glass tube between both ends at a prescribed pitch along the axis

of the tube.

Further, in the fluorescent lamp according to the present invention, the discharge medium is composed of xenon-gas or a mixture of xenon gas and other rare gas.

Further, in the fluorescent lamp according to the present invention, the outer surface of the outer electrode is covered with a translucent resin film layer togather with the glass tube and thereby, the outer electrode is fixed to the outer surface of the glass tube in one united body.

Further, the fluorescent lamp according to the present invention comprises a glass tube with a fluorescent substance coated on the inner wall surface and a sealing portion formed at each of both ends so that discharge medium is filled therein, a first feeding lead wire penetrating one of the sealing portion of the glass tube airtight, an inner electrode connected to the end of the feeding lead wire extended into the glass tube, a second feeding lead wire of which one end is buried in the other sealing portion of the glass tube and the other end is lead out of the glass tube, and an outer electrode composing of a conductor of which end is electrically connected to the second feeding lead wire and mechanically fixed thereto.

Further, in the fluorescent lamp according to the present invention, the second feeding lead wire one end of which is buried in the other sealing portion of the glass

tube is not exposed to inside of the glass tube.

Further, in the fluorescent lamp according to the present invention, the end of the conductor forming the outer electrode is wound around the second feeding lead wire.

Further, in the fluorescent lamp according to present invention, the end of the conductor comprising the outer electrode is wound around the second feeding lead wire in the same winding direction as that of the conductor on the outer surface of the glass tube.

Further, in the fluorescent lamp according to the present invention, the outer surface of the glass tube including the outer electrode is covered with a translucent resin film layer and thereby, the outer electrode is fixed on the outer surface of the glass tube in one united body.

Further, in the fluorescent lamp according to the present invention, the second feeding lead wire of which one end buried in the other sealing portion has an engaging portion formed at that end.

Further, in the fluorescent lamp according to the invention, the discharge medium is composed of xenon gas or a mixture of xenon gas and other rare gas.

Further, a fluorescent lamp according to the present invention comprising a glass tube with sealing portions formed at its both ends, a fluorescent substance film formed on the inner wall surface of the glass tube, a discharge

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medium containing rare gas filled in the glass tube, a first feeding lead wire connected airtight by penetrating one of the sealing portions of the glass tube; an inner electrode provided at the end of the first feeding lead wire, a second feeding lead wire one end of which is buried in the other sealing portion of the glass tube and the other end is led out from the glass tube, a locating portion formed on the outer surface of the glass tube, and an outer electrode which is a conductor guided by the locating portion and is spirally wound around the outer surface of the glass tube the almost overall length of the glass tube with its one end connected and fixed to the second feeding lead wire.

Further, in the fluorescent lamp according to the present invention, the outer surface of the glass tube including the outer electrode is covered with a translucent resin film layer and thereby, the outer electrode is fixed to the outer surface of the glass tube in one united body.

Further, in the fluorescent lamp according to the present invention, the discharge medium is composed of xenon gas or a mixture of xenon gas and other rare gas.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a fluorescent lamp showing a first embodiment of this invention;

FIG. 2 is a diagram showing a vertical sectional view

of the fluorescent lamp shown in FIG. 1 and explaining a structure with a lighting circuit added;

FIG. 3 is a vertical sectional view showing an enlarged one end of the fluorescent lamp shown in FIG. 2;

FIG. 4 is a vertical sectional view showing the fluorescent lamp in another embodiment of this invention;

FIG. 5 is a vertical sectional view of the fluorescent lamp shown in FIG. 4 and for explaining the structure with a lighting circuit added;

FIG. 6 is a vertical sectional view showing an enlarged one end of the fluorescent lamp shown in FIG. 5;

FIG. 7 is a schematic diagram for explaining the winding process to form an outer electrode around the fluorescent lamp shown in FIG. 4, in which (a) is a top view and (b) is a sectional view;

FIG. 8 is a diagram showing the driving conditions of the fluorescent lamp of the present invention by a lighting power source 18 shown in FIG. 5;

FIG. 9 is also a diagram showing the driving conditions of the fluorescent lamp of the present invention by the lighting power source 18 shown in FIG. 5;

FIG. 10 is graphs plotted for obtaining pulse frequency areas for stable light output at a given lamp tube power with tube powers (watt) and driving pulse frequencies taken at the axis of abscissas and the axis of ordinates, respectively;

FIG. 11 is a graph showing light output intensity of the fluorescent lamp at tube power in the above embodiment comparing with conventional mercury-type and xenon-type fluorescent lamps;

FIG. 12 is a graph showing relative total luminous flux (%) against duty ratio of dimming signal when the brightness of the fluorescent lamp of the present invention shown in FIG. 4 was controlled using the PWM dimming method;

FIG. 13 is a perspective view showing the structure of a back-lighting unit for liquid crystal displays with the fluorescent lamp of the present invention incorporated;

FIG. 14 is a vertical sectional view showing the fluorescent lamp in another embodiment of the present invention;

FIG. 15 is a graph showing luminance distributions of the fluorescent lamp of the present invention obtained by measuring the luminance along an axis of the glass tube after an external force is applied intentionally having the same level as that normally applied when conveying, handling or operating the fluorescent lamp in the structure described above and then, required high-frequency voltage is applied;

FIG. 16 is a vertical sectional view showing a structure of an end of the fluorescent lamp in another embodiment of the present invention; and

FIG. 17 is a diagram showing modified examples of the

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second feeding lead wire 114b.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below in detail referring to the drawings.

FIG. 1 is a side view showing the construction of a fluorescent lamp according to the present invention, FIG. 2 is a vertical sectional view showing a fluorescent lamp including a lighting circuit, and FIG. 3 is a vertical sectional view showing the fluorescent lamp shown in FIG. 2 including its enlarged end.

In these diagrams, a fluorescent lamp of the invention has a glass tube 11 which functions as a luminous tube and both sides of the glass tube 11 are sealed airtight by sealing portions 12a, 12b. On the inner wall surface of the glass tube 11, a film of fluorescent substance 13 is formed.

Here, the glass tube 11 has an outer diameter of 1.6 to 10 mm and a length of 50 to 500 mm, an airtight inner space is filled with a discharge medium, for example, rare gas like xenon gas or a mixed rare gas mainly composed of xenon gas.

At the sealed portion 12a of the glass tube 11, a first feeding lead wire 14a is provided which is penetrating inside the airtight space and is sealed airtight. A cylindrical inner electrode 15 is provided at the end of

the lead wire that is extended in the airtight space. The inner electrode 15 has a cylindrical body made of, for example, an Ni plate having an inner diameter of about 2.0 mm and a length of about 4.0 mm with a bottom provided at one end of the cylindrical body. Further, in order to lower a tube voltage, it is possible to provide an electron emission substance on the inner and outer surfaces of the inner electrode. The electron emission substance referred to here is an emitter that is used for cold cathode fluorescent lamps and made of primarily, for example, alkaline earth metal of barium oxide and borides of rare earth elements such as boric lanthanum. Further, the inner electrode 15 may be formed in a column, flat or V shape using Ni or Ni metal such as Ni alloy. When forming it in a cylindrical or column shape, it is desirable to form it in the structure of a truncated cone or a cone having an end surface which has a reduced diameter and opposes to the discharge space . Further, the size of the inner electrode is generally 0.6 to 2.0 mm in the outside diameter and 2 to 5 mm long.

Next, the first feeding lead wire 14a is in a linear or bar shape made of kovar or tungsten of about 0.4 mm diameter. One end of the lead wire is connected to a surface of a bottom wall of the cylindrical body by welding or caulking. The other end of the lead wire is led out of the sealed part 12a of the glass tube 11.

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Further, on the outer surface of the glass tube 11, there is provided an outer electrode 16 formed by Ni wire conductor of about 0.1mm diameter spirally coiled around the glass tube along the overall length in the axial direction (not shown) of the tube. The outer electrode 16 can be formed with an Ni or Cu wire of a diameter 0.05 to 0.5 mm. Here, in order to reduce a power loss in the outer electrode, a material of the outer electrode 16 having specific resistance of $2 \times 10^{-4}\,\Omega$cm or less is desirable and its cross sectional shape may be in such circular shapes as a circle, an ellipse (oval), a semicircle or such a polygonal shape as a triangle, a square, a rectangle, a trapezoid or other similar shapes.

The outer electrode 16 is wound around the glass tube 11 along its axis at a prescribed pitch in order to provide almost uniform distribution of luminous intensity along the axis of the tube. That is, although the winding pitch of the outer electrode varies from 0.1 to 10 mm depending on the outer diameter (or an inner diameter) of a glass tube, the winding pitch of the outer electrode is varied and adjusted according to the position of the glass tube in order to provide a prescribed distribution of luminous intensity. For instance, if the winding pitch is narrowed continuously or gradually as it is separated far from the inner electrode, almost uniform luminous intensity characteristic is obtained along the axis of tube.

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The continuous change in the winding pitch referred to here is to change the winding pitch continuously according to a distance along the axis of the tube from the end at which the inner electrode 15 is arranged in the glass tube.

Further, the gradual change of the winding pitch is attained in the cases shown below. That is, the portion of the outer surface of the glass tube on which a conductor is wound is divided into more than 2 sections along the axis of the glass tube , and

(a) the winding pitch is uniform in each section but is gradually changed for each section as the section goes away from the internal electrode;

(b) by setting the winding pitches at both ends of one of adjacent sections as the upper and lower limits, the winding pitch in each section is changed continuously within a range not exceeding these limits and a mean winding pitch per unit length of each section is changed optionally according to a distance from the inner electrode;

(c) the winding pitch in each section is kept constant or changed moderately and is changed rapidly at the boundary of each section; and

(d) the winding pitch is so selected as more than two of the above (a), (b) and (c) are combined.

Thus, when the winding pitch is narrowed according to the distance from the inner electrode 15, an almost

uniform or desired luminous intensity distribution characteristic is obtained along the tube axis.

The outer surface of the outer electrode 16 thus constructed is covered by a resin film layer 17 like, for instance, a translucent heat shrinking tube and is fixed so that the pitch of the electrode does not change in the axial direction. For this resin film layer 17, such tubes or films having moderate heat resistance as heat shrinking polyethylene terephthalate resin, polyimide resin, fluorine contained resin are desirable.

Next, the other sealing part 12b of the glass tube 11 is provided with a second feeding lead wire 14b one side of which is buried therein and the other end is led out of the glass tube. The lead wire 14b should be kept away from contacting a discharge medium. This second feeding lead wire 14b is made of wire rods having an outer diameter of 0.1 to 2.0 mm as, and made of for instance, an Ni wire, a kovar wire or a Dumet wire or a ribbon shaped foil or a thin plate of Ni or Mo. The second feeding lead wire 14b can be buried in the sealing part 12b by forming a bead stem in which the surface of the second feeding lead wire 14b is covered by a glass insulating layer, placing the stem in the end of the glass tube 11, and by sealing the glass tube 11 with heat using a burner. The lead wire 14b can be also buried in the sealing part 1c by inserting one end of the second feeding lead wire 14b into the end of

the glass tube 11 before sealing and by heating the glass tube end using a burner.

Further, metal wires used for this second feeding lead wire 14b can be formed by the same material in its entirety, but different materials may be used for the portions to be buried in the glass tube and those that are led out of the sealing portion and connected with a voltage feed line 18b. For instance, a kovar wire and Dumet wire are used for the portion that is sealed in the glass tube for increasing the sealing strength to the glass.A Ni wire is used for the portion connected to the voltage feed line 18b for increasing weldability.

One end of the outer electrode 16 is connected and fixed to the second feeding lead wire 114b at the portion led out of the glass tube 11 by electric welding, soldering or caulking 19.

Next, prescribed high frequency pulse voltage, for instance, 20 to 100 kHz, 1 to 4 kV pulse voltage is applied between the inner electrode 15 and the outer electrode 16 by a lighting power source 18 including an inverter via the first and second feeding lead wires 14a, 114b and power feed lines 18a, 18b, respectively. As a result, the discharge starts between the electrodes 15 and 16 and ultraviolet rays are radiated in the glass tube 11. The ultraviolet rays thus radiated excite a fluorescent film 13 on the inner surface of the glass tube 11, and is converted

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into visible rays which are radiated to the outside of the glass tube 11. Thus the glass tube 11 functions as a fluorescent lamp.

The fluorescent lamp having the structure according to the invention is able to radiate stabilized fluorescent light at a high luminous intensity based on the discharge of xenon gas.

Further, the inner electrode 15 in the fluorescent lamp of the invention provided at the end of the glass tube 11 is far shorter than the overall length of the glass tube 11. Since the inner electrode has an almost same structure as that used in a conventional xenon type fluorescent lamp having two inner electrodes, the inner electrode can be easily manufactured using a conventional manufacturing technology.

Further, the outer surface of the outer electrode 16 of the fluorescent lamp of the invention is covered and fixed with the heat shrinking resin film layer 17 and therefore, its pitch is always kept at a prescribed value. Thus, the uniform light is emitted along the axis of the tube and a high luminous output can be secured. In other words, in the fluorescent lamp according to the invention having a structure as described above, the outer electrode 16 is wound spirally around the outer surface of the glass tube 11 at a prescribed pitch. Since the irregular winding pitch affects the luminous distribution in the axial

direction of the tube and the light output, the outer surface of the glass tube 11 around which the outer electrode 16 wound is covered by the translucent resin film layer 17 to insulate and protect the outer electrode 16 as well as to closely fix the spirally wound wire to the outer surface of the bulb 11.

Further, since the end of this outer electrode 16 is connected to the second feeding lead wire 114b by the solder 19 and one end of the second feeding lead wire 114 is buried in the other sealed portion 12b of the glass tube 11, variation in the winding pitch or disconnection resulting from an external force applied to the outer electrode 16 can be prevented. That is, since the outer electrode 16 is made of a thin conductor having a diameter below 0.5 mm, its tensile strength is limited. The disconnection is liable to occur when the wire forming the outer electrode 16 is wound around the outer surface of the glass tube 11, when the wiring to the light power source 18 is made or when incorporating the fluorescent lamp in liquid crystal display systems. Suppose a large external force is applied to the outer electrode 16, so that the resin film layer 17 was damaged, the outer electrode 17 may be dislocated and variation in the winding pitch may be caused.

According to the invention, however, since the second feeding lead wire 114b is provided as described above and the leading end of the outer electrode 16 is connected and

fixed thereto, the above-mentioned problem was solved and a fluorescent lamp which always provides a stable high luminous output could be obtained.

FIG. 4 through FIG. 6 are diagrams showing a second embodiment of this invention. FIG. 4 is a side view of a fluorescent lamp, FIG. 5 is a vertical sectional view of a fluorescent lamp including a lighting circuit, and FIG. 6 is a vertical sectional view of the enlarged end of a fluorescent lamp shown in FIG. 5. In these diagrams, the substantially same component elements as those of the fluorescent lamp shown in FIG. 1 through FIG. 3 are assigned with the same reference numerals and their explanations are omitted, and different component elements will be explained in the following.

According to the second embodiment of the present invention, the glass tube 11 has an outer diameter of 3.0 mm and a length of 176 mm. A phosphor layer 13 mixed with these colors of R, G, and B is formed on the inner wall, and a mixture of xenon and neon gases is used as a discharge medium.

The end of a conductor 16b of the outer electrode 16 wound spirally around the outer surface of the glass tube 11 is wound around the second feeding lead wire 114b and connected by the electric welding or soldering as shown in an enlarged figure of FIG. 6. The end of conductor 16b is wound around the second feeding lead wire 114b in the

same winding direction as that on the outer surface of the glass tube 11.

This structure of the outer electrode 16 is effective in the manufacturing process wherein a thin conductor composing the outer electrode 16 is wound around the outer surface of the glass tube 11 at a prescribed pitch using a winding machine. FIG. 7 is a diagram roughly showing such a winding process and (a) is a top view and (b) is a sectional view. As shown in this diagram, while rotating the glass tube 11 at a constant speed in the direction of arrow A using the tube axis as a rotary axis, the glass tube 11 is moved in the axial direction of the tube (an arrow B) at a speed corresponding to the winding pitch. Then, a metal wire 72 applied with a definite tension from a metal wire nozzle 71 arranged in the direction perpendicular to the glass tube 11 is supplied. The winding of the wire using such a winding machine starts at the portion of second feeding lead wire 114b buried in the end of the glass tube 11. At the time when the winding starts, the moving speed of the glass tube 11 in the direction of arrow B is lowered and a wire is wound closely to the root of the second feeding lead wire 114b at an almost zero winding pitch. Then, the moving speed of the glass tube 11 in the direction of arrow B is raised and the wire is wound around the outer surface of the glass tube 11 at a prescribed winding pitch. In this case, when the moving speed of the glass

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tube 11 in the direction of arrow B is gradually raised, the winding pitch can be made large. Accordingly, the outer electrode 16 can be wound spirally so that the winding pitch is slowly narrowed from the end 12a where the inner electrode 15 is arranged in the glass tube 11 toward the opposite end 12b.

Further, the winding of the outer electrode 16 starts from the second feeding lead wire 14b portion and its end is fixed at this portion as it is thickly wound here and therefore, the outer electrode can be wound at an accurate pitch since there is no loosening or dislocating of the wire during it is wound.

Furthermore, since the end of winding is fixed at the second feeding lead wire 14b even after completing the winding, the winding does not loosened nor dislocated when it is wound, incorporated in liquid crystal display systems or conveyed and thereby providing the accurate winding pitch.

FIG. 8 and FIG. 9 show the driving conditions of a fluorescent lamp of the invention by the lighting power source 18 shown in FIG. 5. In the case of a xenon-type fluorescent lamp, a positive column tends to become a thin stripe (a constricted positive column) moving irregularly and therefore, there is a tendency that the light output becomes unstable and low. To prevent the formation of this constricted positive column, it is normally required to

use a pulse power source and adjusting its frequency.

FIG. 8 (a) is a graph experimentally showing the relation between such a lamp driving pulse waveform and the discharge current of a fluorescent lamp. That is, when a driving pulse of peak voltage of 1 kV, pulse power of 3.0W, frequency of 40 kHz and a waveform having a duty ratio (D) of 45% was used, the suspended term of a discharge current waveform was 7 μsec. As a result, a constricted positive column portion 82 in the positive column 81 reached to the central portion of the glass tube 11 and the unstable luminous operation was presented as shown in FIG. 8(b).

FIG. 9(a) is a graph experimentally showing the relation between a pulse waveform and a discharge current of a fluorescent lamp at the operating frequency of 20 kHz with the same conditions other than the frequency. The suspended term of the discharge current waveform was 18 μsec in this case and it was confirmed that no constricted positive column is formed. The positive column 91 is diffused toward the diameter of he glass tube 11 (a diffused positive column) over the almost overall area of the glass tube 11 and a stable operation is obtained in which sufficient ultraviolet rays are output as shown in FIG. 9(b).

FIG. 10 is a graph plotting a lighting pulse frequency for a stable light output at a given lamp power by taking lamp power (power supplied to a lamp at the time of lamp

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discharge. Unit is watt.) and lighting frequency of driving pulse at the horizontal and vertical axes, respectively. According to the graph, the lamp operating state is divided into a stable light output area 101, an unstable light output area 102 and a light output area of insufficient intensity 103. In FIG. 10,(a), (b) and (c) show the graphs at the discharge gas pressures 8.0 kPa, 13.2 kPa and 18.6 kPa, respectively. From these graphs experimentally obtained it is seen that a stable light output area 101 can be expanded by increasing gas pressure.

FIG. 11 is a graph showing the luminous intensity of a fluorescent lamp according to the above embodiment for the lamp power by comparing those of a conventional mercury and xenon fluorescent lamps. In the figure,a curve 121 in FIG. 11 shows a relative total luminous flux (%) of the fluorescent lamp of the invention. A curve 122 shows that of a conventional mercury-type fluorescent lamp provided with two inner electrodes. A curve 123 shows that of a conventional xenon-type fluorescent lamp provided with two inner electrodes and driven by pulse. Finally, a curve 124 shows that of a conventional xenon-type fluorescent lamp provided with two inner electrodes and driven by sine wave.

As seen from this graph, the total flux of the fluorescent lamp of the invention is as much as twice of a conventional xenon-type fluorescent lamp and reaches to 50% as much as that of a conventional Hg-type fluorescent

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lamp.

Further, the fluorescent lamp of the invention has a stable light output characteristic without flickering even when the brightness is controlled for the wide dimming range from 2% to 100%. FIG. 13 is a graph showing a relative total luminous flux (%) for the duty ratio of the dimming signal when the brightness is controlled by a PWM-dimming method.

FIG. 13 is a perspective view showing the structure of a back-lighting unit for a liquid crystal display with the fluorescent lamp of the invention incorporated. This back-lighting unit is for a 7 inch size liquid crystal display panel. Two fluorescent lamps 142 are arranged at each side of a light guide plate 141. Two fluorescent lamps 142 at each side of the light guide plate 141 are accommodated in a reflector 143. On the top of the light guide plate 141, a prism sheet and a diffusion sheet 144 are laminated, reflecting sheets 145 are laminated on the bottom surface of the plate 141.

The thickness of the thus constructed back-lighting unit is 11 mm. When the total lamp power is 11W, the luminance of the back-lighting unit is 6,000 cd/m² was obtained, which is sufficient enough for the back-lighting unit for a car-navigation display.

FIG. 14 is a vertical sectional view showing a fluorescent lamp according to other embodiment of the

invention. In FIG. 14, the same component elements as those shown in FIG. 1 through FIG. 3 are assigned with the same reference numerals and further explanations thereof are omitted.

The fluorescent lamp shown in FIG. 14 has one or plural number of locating portions 11a for winding consisting of, for instance, a groove or concavo-convex portion formed on the outer surface of the glass tube 11. The locating portions 11a are provided at both ends where the winding of a conductor comprising the outer electrode 16 starts and ends they also may be provided at the middle part between the both ends on the outer surface of the glass tube 11. These locating portions 11a are formed in advance continuously or at proper intervals in accordance with the winding pitch of the outer electrode 16, which varies successively or in step wise along the axis of the glass tube 11 as described above. When a conductor is wound using these locating portions 11a as guides, the winding at an accurate pitch space as designed is enabled and the winding work becomes easy.

Further, the outer surface of the glass tube 11 including the outer electrode 16 is covered by the translucent resin film layer 17 such as a heat shrinking resin tube, which fixes the outer electrode 16 on the outer surface of the glass tube 11 similarly to the first and second embodiments. Further, the end 16b of the outer

electrode 16 is connected and fixed by being wound around the second feeding lead wire 114b, one end of which is buried in the other sealing portion 12b of the glass tube 114b. Accordingly, even when an external force is applied to the outer electrode 16, the movement of the conductors in the axial direction of the tube is suppressed. The uneven distribution of luminous intensity in the axial direction of the glass tune is, thereby, sharply improved without any drop of the light output.

Further, the locating portions 11a are not restricted to a hollow shaped groove but can be of convex shape of glass. They may be concavo and convex shaped portions which fix the outer electrode 16 between them. Further, locations and the numbers of the locating portions are selectable depending upon the necessity.

FIG. 15 is a graph showing luminous distributions of a fluorescent lamp having a structure described above, which is obtained by measuring the luminance along the axis of a glass tube being applied with a required high frequency voltage after an external force is applied of the same level normally applied during conveying or operating a fluorescent lamp. As shown by a curve A in FIG. 15, it was confirmed that the fluorescent lamp of the invention presents almost uniform luminance on the overall length of the glass tube. Further, a curve B in FIG. 15 shows the luminous distribution when the outer electrode 16 was

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directly pulled out without connected to the second feeding lead wire 114b, and an external force similar to that shown above was applied to a fluorescent lamp which has no locating portions 11a formed on the outer surface of the glass tube 11 in order for comparing with the fluorescent lamp of this invention.

Further, in the graph shown in FIG. 15, the axis of abscissas shows a distance (cm) from the end 12a of the glass tube 11 where the inner electrode 15 is provided and the axis of ordinates shows luminance (cd/m^2), respectively.

FIG. 16 is a vertical sectional view further showing the structure of the end portion of the fluorescent lamp according to the further embodiment of the invention. In the diagram, the component elements that are substantially the same as those of the fluorescent lamp in the above embodiments are assigned with the same reference numerals and the further explanations thereof are omitted.

In the embodiments described above, the second feeding lead wire 114b one end of which is buried in the other sealing portion 12b of the glass tube 11 is closely fixed and firmly secured in the sealing portion when its coefficient of thermal expansion is close to that of the sealing portion 12b. However, when their coefficients of thermal expansion differ largely or when a heating burner has some defects while forming the sealing portion 12b, the close

contact of the second feeding lead wire 114 with the glass sealing portion 12b becomes insufficient. As a result, the second feeding lead wire 114b may possibly come off from the sealing portion 2b while wiring with the lighting power source, conveying or incorporating into the display system the fluorescent lamp.

According to the embodiment, therefore, a portion 172 which has a diameter larger than that of a lead wire body 171 is formed at the end portion of the second feeding lead wire 114b that is to be buried in the sealing portion 2b as shown in FIG. 16.

In addition, FIG. 17(a) through (d) show modified examples of the second feeding lead wire 114b. That is, in the second feeding lead wire 114b shown in FIG. 17(a), a rough surface portion 181 is formed on the end to be buried in the sealing portion 12b by the etching process or a plating process (build-up). In the lead wire 114b shown in FIG. 17(b), a concavo-convex portion 182 is formed at the end portion by cutting or chipping. In the lead wire 114b shown in FIG. 17(c), a bent portion 183 is formed by bending the end portion and in the case of the second feeding lead wire 114b shown in FIG. 17(d), a flat portion 184 wider than the rest of the lead portion is formed by crushing the end portion.

Since these second feeding lead wires 114b have such engaging portions as the large diameter portion 172, the

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rough surface portion 181, the concavo-convex portion 182, the bent portion 183 or the flat portion 184 formed at the end portions, melted glass fills around the end portion when it is buried in the sealing portion 12b of the glass tube 11. After the glass being hardened, even if the close contact between the lead wire and the glass is insufficient, the second feeding lead wire 114b can be prevented from coming off in the axial direction.

Further, the present invention is not limited to the embodiments described above but can be modified variously within the scope of the invention. For example, material, outer diameter, length, shape of the glass tube, material, shape and engaging means of the outer electrode, material shape and arrangement of the inner electrode, material of the translucent resin film layer or kind of gas can be modified by the necessity to cope with the purpose of use and using condition of a fluorescent lamp.

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